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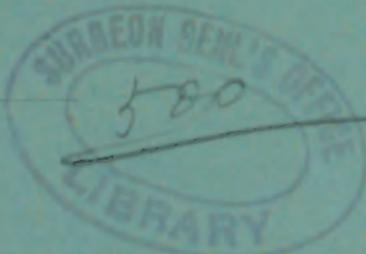
EFFECT OF CARBON DIOXID, CARBONIC OXID,
SULPHURETED HYDROGEN, WATER-GAS
AND COAL-GAS ON ANIMAL LIFE.

BY

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EFFECT OF CARBON DIOXID, CARBONIC
OXID, SULPHURETED HYDROGEN, WATER-
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As the health of every individual is dependent upon the purity of the atmosphere, a knowledge of the effect on animal life of impurities in the air is of the highest importance to the community at large, but of special importance to those who work in coal, silver, lead, copper, or gold mines, or at iron furnaces, coke ovens, etc. In such places impurities often exist, such as

	S. D.
CO ₂ —"Choke-damp," or carbon dioxid . . .	1.529
CO—"White damp," or carbonic oxid . . .	0.9678
H ₂ S—Sulphureted hydrogen, or hydrogen sulphid	0.1912

The statistics compiled by me from the indices of the library of the College of Physicians, Philadelphia, one of the most complete institutions in the world, show that 90 per cent. of the total scientific experiments on the effects of noxious gases on animal life have been made by the Germans and

¹ A lecture delivered before the students and Faculty of the Philadelphia College of Pharmacy, November 21, 1893.



the French, and for the last decade scarcely any experiments have been made by scientists of any nationality, the results obtained by our forefathers being accepted with a credulity seldom encountered in other branches of science. In addition to this, the poverty of information in the standard references on this subject is so great that were any particular knowledge required, it would be necessary to make new experiments. With these facts before me, in grouping the results obtained in experiments with carbon dioxid, carbonic oxid, and sulphureted hydrogen on animal life, the medical fraternity will at least have a condensation of experiments for reference from many authorities, combined with the results of my own experiments. I claim that my experiments are absolutely accurate, as the means employed for mixing the different atmospheres (the Shaw gas-tester) is acknowledged to be as nearly perfect as human agency can make anything, and has been awarded the Elliott Cresson and the Scott Legacy medals for accuracy—the highest awards in the gift of the Franklin Institute. This tester is to gases what weights and scales are to solids.

It is not my intention to go into the constituents of the gases named, there being no necessity for my doing so in this paper. I have simply one object in view: to describe, as the result of recent experiments, the effect produced by them on animal life. The Shaw gas-tester, which I used for mixing my gases in the centesimal proportions desired, is an apparatus simple, convenient, and accurate, consisting of two pumps with pistons attached to a

graduated arm, so that one cylinder can be set to pump 10 per cent. of gas and the other 90 per cent. of air, or *vice versa*, or any per cent. to the lowest fraction. It is the only instrument in the world capable of mixing gases accurately, rapidly, and continuously in any per cent. desired, the product of the two cylinders being forced through an injector or mixer before delivery.

The animal under treatment is placed in a bell-shaped glass cylinder sixteen inches high, of four inches diameter at the neck and eight inches at the base. The cylinder is placed horizontally on the table, with the neck toward the operator, and is connected with the instrument at the neck by means of a rubber tube. The animal rests on all fours, facing the operator, with its nose near the aperture through which the gases enter the cylinder from the instrument or mixer.

The end of the bell-shaped glass cylinder is entirely open to the air, so that the mixture of gas and air is discharged and replaced every four seconds by each stroke of the pump, always maintaining a constant mixture, preventing stratification or contamination through the exhalations of the animal. The cylinder, being of glass and perfectly transparent, enables the operator to observe every change in the condition of the animal.

The difference in results obtained by the various authorities has caused me to make the following experiments to satisfy myself, an accurate knowledge on this subject being necessary to the pursuit of my profession, and I am well aware of the great difficulties experienced by my predecessors in making

accurate mixtures of gases, owing to the crude appliances for this purpose at their command.

As a prelude to my experiments I will give the results obtained with carbon dioxid by scientists whom we are accustomed to quote :

CARBON DIOXID.

	Per cent.
J. H. Merrivale says: It extinguishes lights and is fatal to animal life.	
J. J. Atkinson says: Dangerous to life	8
Lights extinguished	10
Fairley's <i>Catechism</i> : Dangerous to life	3
Will cause death quickly	10
Light will burn in	10 to 20
Sir H. Roscoe's <i>Chemistry</i> : Will not support combustion of candle	3 to 6
Dr. A. Smith: Lights extinguished	about 2
Would suffocate	4

Watts' *Dictionary of Chemistry* says: "Animals immersed in it soon die, not only from want of oxygen, but in consequence of a direct poisonous action, violent spasms being sometimes produced; sometimes complete atony of the cerebral faculties."

The *Encyclopedie Britannica*, vol. v, p. 87, says: "Will not burn, neither does it support combustion."

Dr. Karl Friedlander, of Berlin, in experiments on animal life states that "62.8 per cent. killed a rabbit in twenty-seven minutes; 65 per cent. killed a rabbit in forty-five minutes," the higher per cent. in this instance taking longer to kill the rabbit than the lower per cent., showing a wide variation in his tests, which I can only account for by the imperfect appliances at his command for placing definite quantities of gas in the atmosphere, and maintain-

ing a constant mixture of definite proportions. Rabbits, like human beings, have their ailments, and I have found in the course of my experiments that disease, in the shape of a fatty accumulation about the heart, disqualifies the animal entirely for tests of this nature, death resulting in one-tenth of the time necessary to produce the same result in a perfectly healthy animal; but in the foregoing instance the difference in time of immersion in such a high per cent. is not great enough for me to ascribe the difference in effect to any organic disease, but rather to the imperfect mixing of the gases.

In all of my experiments I have found that the smaller the animal the sooner it succumbed to poisonous gases. My first experiments were made with small birds; then I tried mice, after which I bestowed my attention on guinea-pigs, finally selecting the rabbit upon which to conduct the experiments herewith presented.

EXPERIMENTS WITH CARBON DIOXID.

EXPERIMENT No. 1. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 10 per cent. of CO_2 and 90 per cent. of air. After one hour and seven minutes the rabbit gave no indication whatever of being affected, so I released it and allowed it to run with several others of its species, the effect of its treatment, contrary to expectation, being great exhilaration instead of stupefaction.

Result. 10 per cent. of CO_2 and 90 per cent. of air; one hour and seven minutes' inhalation—exhilaration.

No. 2. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 25 per cent. of CO_2 ,

and 75 per cent. of air for one hour, at the end of which time the animal showed no indication whatever of being affected, and when released and placed with others exhibited as much liveliness as they.

Result. 25 per cent. of CO_2 and 75 per cent. of air; one hour's inhalation—unaffected.

No. 3. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 50 per cent. of CO_2 and 50 per cent. of air. At the end of two minutes the rabbit showed signs of being affected; at the end of three minutes it commenced to gasp regularly every two seconds; at the end of six minutes the gasps were three seconds apart; ten minutes, the gasps were four seconds; twelve minutes, the gasps were six seconds; fourteen minutes, the gasps were eight seconds; fifteen minutes, the gasps were nine seconds; sixteen minutes, the gasps were ten seconds; seventeen minutes, death ensued.

Result. 50 per cent. of CO_2 and 50 per cent. of air; seventeen minutes' inhalation—death.

No. 4. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 75 per cent. of CO_2 and 25 per cent. of air. At the end of two minutes the rabbit commenced to pant rapidly; three minutes, it became stupefied and gasped every two seconds; five minutes, the gasps were three seconds apart; seven minutes, the gasps were five seconds; eight minutes, the gasps were six seconds; nine minutes, the gasps were ten seconds; ten minutes, death ensued.

Result. 75 per cent. of CO_2 and 25 per cent. of air; ten minutes' inhalation—death.

No. 5. I placed a mouse in a glass cylinder and pumped in an atmosphere of pure CO_2 ; death was instantaneous.

Result. Pure CO_2 ; death instantaneous.

No. 6. I placed a mouse in a glass cylinder and pumped in an atmosphere of 25 per cent. of CO_2 ,

and 75 per cent. of air. At the end of three minutes the mouse seemed slightly affected, but kept moving around the cylinder—in this test held vertically. At the end of ten minutes the conditions were unchanged, and I displaced the atmosphere of 25 per cent. CO_2 with pure air. The mouse revived instantaneously on the first inhalation.

Result. 25 per cent. of CO_2 and 75 per cent. of air; ten minutes' inhalation; slightly affected, but recovered instantaneously in the fresh air.

No. 7. I placed a mouse in a glass cylinder and pumped in an atmosphere of 50 per cent. of CO_2 and 50 per cent. of air. At the end of ten seconds the mouse showed great exhilaration; twenty seconds, its activity was greatly reduced; thirty seconds, it became stupefied; thirty-five seconds, gave short gasps; forty-five seconds, the gasps were long and apparently painful; fifty-five seconds, death occurred.

Result. 50 per cent. of CO_2 and 50 per cent. of air; fifty-five seconds' inhalation—death.

Experiments 5, 6 and 7, are only given here to illustrate the fact that the smaller the animal the less the power of resistance to CO_2 .

EXPERIMENTS WITH CARBONIC OXID.

The results obtained by scientists whom we are accustomed to quote, on the effect of carbonic oxid on animal life, are first epitomized.

H. Letheby, M.B., M.A., Ph.D., etc. late Professor of Chemistry and Toxicology in the Medical College of the London Hospital, says that 0.5 of 1 per cent. of CO killed small birds in three minutes; 1 per cent. in half the time; 2 per cent. renders guinea-pigs insensible in two minutes. In all cases the effects

were the same. The animals showed no signs of pain; they fell insensible and either died at once with a slight flutter, hardly amounting to a convulsion, or gradually slept away as if in profound slumber. The post-mortem examination showed the blood to be a little more deeply red than usual.

Prof. A. R. Leeds says: "The operation of pure CO is so immediate as to prevent the lungs throwing off a single charge received."

Watts' *Dictionary of Chemistry* says: "It is a very poisonous gas, acting chiefly on the nervous system, causing giddiness when inhaled, sometimes acute pain in various parts of the body, and after a while complete asphyxia."

Buck, on *Hygiene and Public Health* says: "It is not so immediately fatal as carbonic acid gas."

The *Encyclopedie Britannica*, vol. v, p. 87, says: "It is an extremely poisonous gas, being capable of displacing the oxygen in the blood, owing to a compound with the hemoglobin with which the oxygen is ordinarily combined."

The *American Encyclopedia*, vol. iii, p. 775, says: "It is more irrespirable and poisonous than carbon dioxid. Its inhalation from furnaces sometimes causes immediate asphyxia to the workmen."

I will now submit the results of my own experiments on the effect of carbonic oxid on animal life, but have to omit several important tests owing to the carelessness of a servant in destroying my notes.

No. 1. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 2 per cent. of CO, and 98 per cent. of air. At the end of ten minutes the posterior extremity of the rabbit became par-

alyzed ; at the end of eighteen minutes the fore-legs became paralyzed, and at the end of twenty minutes the rabbit became semi-comatose ; at the end of forty-five minutes its condition had not altered ; on being placed in the fresh air it revived sufficiently to maintain its equilibrium.

Result. 2 per cent. of CO and 98 per cent. of air ; revived in fresh air after forty-five minutes' inhalation of the gas.

No. 2. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 2.5 per cent. of CO and 97.5 per cent. of air. At the end of five minutes the rabbit became semi comatose, but on being placed in the pure air, it recovered almost immediately.

Result. 2.5 per cent. of CO, and 97.5 per cent. of air ; revived in fresh air after inhalation of the gas five minutes.

No. 3. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 4 per cent. of CO, and 96 per cent. of air. Death resulted in four and one-half minutes.

Result. 4 per cent. of CO and 96 per cent. of air ; four and one-half minutes' inhalation ; death.

No. 4. I placed a mouse in a glass cylinder and pumped in an atmosphere of 0.2 of 1 per cent. of CO and 99.8 per cent. of air. At the end of six minutes the mouse showed no signs whatever of being affected.

No. 5. I then increased the atmosphere to 0.5 of one per cent. of CO and 99.5 per cent. of air. At the end of five minutes the mouse showed no signs whatever of being affected.

No. 3. I now increased the atmosphere to 1 per cent. of CO and 99 per cent. of air. At the end of thirty minutes, the mouse showed no signs of being affected. I then gave it fresh air for one minute, and increased the atmosphere to 2 per cent. of CO,

and the mouse died in ten minutes with a total relaxation of all the muscles.

Result. 2 per cent. of CO and 98 per cent. of air ; ten minutes' inhalation ; death.

No. 7. I placed a mouse in an atmosphere of 2.5 per cent. of CO and 97.5 per cent. of air, and the mouse died in five minutes.

Result. 2.5 per cent. of CO and 97.5 per cent. of air ; five minutes' inhalation ; death.

No. 8. I placed a mouse in an atmosphere of 10 per cent. of CO and 90 per cent. of air, death resulting in three minutes.

Result. 10 per cent. of CO, and 90 per cent. of air ; three minutes' inhalation, death.

In the absence of the missing tests, I have included experiments Nos. 4, 5, 6, 7, and 8, simply to illustrate the fact that the smaller the animal, the less the power of resistance to CO.

SULPHURETED HYDROGEN.

I note again the results obtained by scientific authorities whom we are accustomed to quote, on the effect of sulphureted hydrogen on animal life.

Watts' *Dictionary of Chemistry*, p. 203, says: "An atmosphere of one-tenth of 1 per cent. of this gas proves fatal to lower animals."

Public Health Reports and Papers, vol. iii, p. 75, 76, says: "It is poisonous, and its action on arterial blood is a common lecture table experiment."

The *Encyclopedia Britannica*, article Chemistry, vol. v, p. 500, says: "It cannot be breathed with impunity, frequently giving rise to nausea and vertigo, even when much diluted."

The *American Encyclopedia*, vol. ix, p. 130, says :

"Thenard found that a small bird would die in air containing fifteen one hundredths of 1 per cent. and a horse in air that contained one-quarter of 1 per cent."

The results of my experiments on the effect of H₂S on animal life are as follows:

No. 1. *a.* I placed a rabbit in a glass cylinder and pumped in an atmosphere of 1 per cent. of H₂S and 99 per cent. of air.

b. I placed another rabbit in another glass cylinder and pumped in an atmosphere of 1 per cent. of H₂S, and 99 per cent of air, simultaneously with No. 1, using two Shaw gas-testers as mixers for the operation, both connected with the same bag of H₂S. Death occurred simultaneously in cylinders Nos. 1 and 2, at the end of one minute, preceded by violent convulsions which lasted about ten seconds.

Result. 1 per cent. of H₂S and 99 per cent. of air; one minute's inhalation; death.

No. 2. *a.* I placed a rabbit in a glass cylinder No. 1, and pumped an atmosphere of 0.5 of 1 per cent. of H₂S and 99.5 per cent. of air.

b. I placed another rabbit in a glass cylinder No. 2, and pumped in an atmosphere of 0.5 of 1 per cent of H₂S and 99.5 per cent. of air simultaneously with No. 1, using two Shaw gas testers as mixers for the operation, both connected with the same bag of H₂S. Death occurred simultaneously in cylinders 1 and 2 at the end of three minutes, preceded by violent convulsions which lasted about fifteen seconds.

Result. 0.5 of 1 per cent. of H₂S and 99.5 per cent. of air; three minutes' inhalation; death.

No. 3. *a.* I placed a rabbit in glass cylinder No. 1 and pumped in an atmosphere of 0.2 of 1 per cent. of H₂S and 99.8 per cent. of air.

b. I placed another rabbit in a glass cylinder No. 2, and pumped in an atmosphere of 0.2 of 1 per cent. of H_2S and 99.8 per cent. of air, simultaneously with No. 1, using two Shaw gas-testers as mixers for the operation, both connected with the same bag of H_2S ; death resulted simultaneously in cylinders Nos. 1 and 2 at the end of ten minutes.

Result. 0.2 of 1 per cent. of H_2S and 99.8 per cent. of air; ten minutes' inhalation; death.

No. 4. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 0.1 of 1 per cent. of H_2S , or the 0.001 part, and 99.9 per cent. of air; death resulted in thirty-seven minutes.

Result. 0.1 of 1 per cent. H_2S , or the 0.001 part, and 99.9 per cent. of air; thirty-seven minutes' inhalation; death.

NOTE.—In all of the foregoing tests the rabbits were seized with convulsions from ten to fifteen seconds after immersion in the poisonous atmosphere, which lasted on an average about twelve seconds.

No. 5. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 0.025 of 1 per cent. of H_2S and 99.975 per cent. of air. At the end of two hours the rabbit showed no signs whatever of being affected, so I released it.

Result. 0.025 of 1 per cent. of H_2S and 99.975 of air; two hours' inhalation; unaffected.

EFFECT OF ILLUMINATING OR COAL AND WATER GAS ON ANIMAL LIFE.

The frequent occurrence of accidental deaths from illuminating gas has caused me to make a series of experiments on this subject, with a view to determining just how much risk we run in having a small escape of gas in our bed-rooms, for instance, and

the results obtained ought to act as a warning to all who are in any way careless in turning off the stop-cocks before retiring, or who carelessly turn the gas low near a draught, and find it blown out the next morning and the room filled with gas.

No. 1. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 75 per cent. of illuminating gas (water and coal gas) and 25 per cent. of air. The rabbit was immediately seized with violent convulsions and death ensued in two minutes.

Result. 75 per cent. of illuminating gas (water and coal gas) and 25 per cent. of air; two minutes' inhalation; death.

No. 2. I placed a rabbit in a glass cylinder and pumped in 25 per cent. of illuminating gas (water and coal gas) and 75 per cent. of air; on the third inhalation the rabbit was seized with violent convulsions and urinated freely; at the end of one minute the convulsions ceased, and at the end of four minutes death ensued.

Result. 25 per cent. of illuminating gas (water and coal gas) and 75 per cent. of air; four minutes' inhalation; death.

No. 3. I placed a rabbit in a glass cylinder and pumped in 15 per cent. of illuminating gas (water and coal gas) and 85 per cent. of air; without any struggling it sank into a comatose state; at the end of three minutes it struggled feebly; at the end of four minutes urinated, and at the end of six minutes died.

Result. 15 per cent. of illuminating gas (water and coal gas) and 85 per cent. of air; six minutes' inhalation; death.

No. 4. I placed a rabbit in a glass cylinder and pumped in 10 per cent. of illuminating gas (water and coal gas) and 90 per cent. of air; at the end

of thirteen minutes the rabbit was seized with a convulsion and died in five seconds.

Result. 10 per cent. of illuminating gas (water and coal gas) and 90 per cent. of air; thirteen minutes' inhalation; death.

No. 5. I placed a rabbit in a glass cylinder and pumped in an atmosphere of 5 per cent. of illuminating gas (water and coal gas) and 95 per cent. of air; at the end of ten minutes the rabbit was seized with severe convulsions, which lasted twenty seconds; at the end of twenty minutes it commenced to gasp, and at the end of thirty minutes death ensued.

Result. 5 per cent. of illuminating gas (water and coal gas) and 95 per cent. of air; thirty minutes' inhalation; death.

I did not analyze the illuminating gas for its constituents, but the gas used was Philadelphia City gas, and I believe that it contains about 30 per cent. of CO.

I have other experiments on hand on CH_4 , carbureted hydrogen, or fire-damp; also on the effect of carbon dioxid, or choke-damp, on lights, the results of which it will afford me pleasure to make known in my next paper.

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